Chapter 1

STRANGE BARYON AND H-DIBARYON MEASUREMENTS IN AU-AU COLLISIONS IN AGS EXPERIMENT E896

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Abstract The primary goal of E896 at the AGS was to perform a definitive search of the H-Dibaryon in central Au-Au collisions. In addition E896 has measured strange meson and baryon distributions at mid-rapidity. The different components of the experiment will be presented, with special emphasis on the first successful tracking detector based on Silicon Drift Detector technology. The physics motivation for the H-Dibaryon search as well as the measurement of strange baryon abundances will be detailed. Finally, preliminary results of the ongoing analysis will be shown.

Keywords: AGS, Quark Gluon Plasma, Strangeness Production, H-Dibaryon

1. INTRODUCTION

Experiment E896 at the AGS has two main goals, namely to perform a definitive search for the H-Dibaryon and to measure the production of strange mesons and baryons in central Au-Au collisions at 11.6 GeV/c. The experiment took data during a four week period in April '98 at the AGS at BNL.

The detector consists of two main, and largely independent, components. A Silicon Drift Detector Array (SDDA) is mounted very close to the target in a strong magnetic field (B = 6T). A Distributed Drift Chamber (DDC) is mounted in a moderate dipole field (B = 1.5T). The second magnet is located in such a way that the sweeping magnet removes most charged particles and the beam itself from the active area of the DDC, so that only neutral primary particles will reach the detector. The DDC is backed up by a time of flight array (TOF) and a neutron detector (MUFFINS) outside of the magnetic field. Two beam vectoring low pressure drift chambers were installed upstream of the target. A forward multiplicity array was used to determine the centrality of the interaction for trigger purposes. A schematic setup of the complete experiment was shown in the Proceedings of the 1997 Nuclear Dynamics Workshop [26].

The goal is to measure the charged decay particles of the H-Dibaryon and of neutral strange particles (Λ, $\overline{\Lambda}$, K_s^0) in the DDC. The distance of the chamber from the target has been optimized for a specific range of H-Dibaryon lifetimes, based on detailed theoretical predictions [1] and prior measurements of Hypernuclei candidates [2]. The rapidity coverage of the DDC ranges from 2.0 to 3.2.

The SDDA is located very close to the target and its primary Physics goal is the detailed measurement of strangeness production at mid-rapidity. Although the charged Kaon distributions in central Au-Au collisions at the AGS have been measured to great accuracy by E866 [3], no systematic measurements of strange baryons and neutral Kaon distributions have been performed yet. Presently two experiments, E917 [4] and E896 are analyzing Λ, $\overline{\Lambda}$, and Ξ^- distributions. These data will complement the extensive CERN program that recently led to spectacular results for the strange baryon enhancement factors [5],[6]. The SDDA covers about one unit of rapidity around mid-rapidity (y = 0.8-2.0). The SDDA consists of 15 layers of Silicon Drift Detectors [7]. The wafers and the electronics modules are prototypes of the production components for the Silicon Vertex Tracker for the STAR-RHIC experiment [8].

2. PHYSICS MOTIVATION

2.1 H-DIBARYON SEARCH

The H-Dibaryon was postulated as a possible metastable state by Jaffe [9] on the basis of detailed calculations in the framework of the MIT Bag Model. Since then, many different Quark models postulated the existence of a bound six-quark state, mostly due to attractive potentials in the color force interaction. At this point the existence of a stable six-quark state and even a weakly decaying six quark state, with Δs=2, can be excluded on the basis of detailed calculations and many experiments. Ashery gave a nice overview presentation at HADRON 97 [10] summarizing the state of H-Dibaryon search results. Presently about 20 experiments have been concluded without yielding any positive results. Based on these results, which were mostly obtained by Kaon induced experiments, and in particular a measurement reported by E836 at the AGS [11], it is safe to conclude that the H-Dibaryon, if existent as a non-resonant state, has to have a mass somewhere between 2200 MeV and 2230 MeV (the $\Lambda\Lambda$ threshold). In 1995 the E810 collaboration reported the discovery of potential H_0 candidates in this mass range in central Si+Pb collisions at the AGS [12]. The strongest branching ratio is believed to be to the Σ^-p channel. The two other possible channels are the $\Lambda p\pi$ channel and the Λn channel. A resonant state could theoretically also decay into the Ξ^-p channel, which can be analyzed as part of the Ξ reconstruction effort. E896 has capabilities to detect all of those channels, with the main emphasis on the Σ^-p channel. The reconstruction of this particular decay is further complicated by the subsequent decay of the Σ into a neutron and a π^-, and thus relies on the detection of a 'kink' at the position of the Σ^- to nπ^- decay.

2.2 STRANGENESS MEASUREMENTS

Recently several model interpretations of the CERN measurements of strangeness production in the light (S+S) and heavy (Pb+Pb) ion systems indicated that the enhancement factors can not be easily interpreted by the simple condition that the system is a very dense hadron gas. If chemical and thermal equilibrium in a hadron gas is assumed [13], the non-strange meson and baryon ratios are well described, but most of the strange and multi-strange baryon ratios can not be fully reproduced. Thus, various statistical models that include a QGP phase transition have been suggested [14],[15]. The latest theory presented by Rafelski at this conference [16], assumes thermal equilibration and explicit chemical non-equilibration to interpret the data. Here, the strangeness ratios are based on sudden hadronization of a QGP phase and no subsequent inelastic scattering to change the particle abundances or ratios. All final state interactions of the heavy baryons are elastic and cause only changes in the kinetic parameters, such as the transverse momentum. Thus chemical and thermal freezeout are decoupled. After hadronization the fireball expands with a well defined expansion velocity. Folding this velocity into the kinetic particle spectra leads to a common thermal freezeout temperature of about 130 MeV, whereas the particle abundance and ratio analysis yields a chemical freezeout temperature close to the critical temperature of about 180 MeV [17]. If the CERN measurements indeed indicate a phase transition, it will be intriguing to show whether these transition signatures in the strange baryon channels are reproduced at the lower AGS energies. On the other hand, many event generators based on hadronic cascade models or string models can describe some of the CERN data, by using specific reaction mechanisms, such as color ropes [18] or quark droplets [19] in a dense hadronic matter system. These models do not require a global phase transition, although both reaction mechanisms could be interpreted as requiring a local transition into the quark condensate. The main ratios that show unusual behavior at the SPS and that have now been measured with the SDDA are the multi-strange to strange baryon ratios (e.g. Ξ^-/Λ) and the anti-baryon ratios (e.g. $\overline{\Lambda}/\overline{p}$).

Fig.1 shows compilations of the most spectacular results from SPS and AGS. Fig.1a shows the strangeness enhancement factors measured in experiment WA97 [6]. pA-yields extrapolated to AA-yields are compared to yields measured in Au-Au collisions. The extrapolation is based on a linear scaling of particle yields with the number of participant nucleons. Fig.1b shows a compilation of NA35/NA49 $\overline{\Lambda}/\overline{p}$ ratios as a function of the participant nucleon number [5]. The additional data points are deduced from two AGS measurements, one a direct ratio measurement by E866 in the Si+Pb system [3], and one an indirect measurement in the Au-Au system which is based on comparing the Anti-Proton yield in two experiments with different Anti-Lambda acceptance (E878 and E864). The comparative method that was applied to this analysis is described in detail in [20]. It is apparent that there seems to be very little energy dependence in the $\overline{\Lambda}$ enhancement. Our group tried to describe those large anti-particle ratios with two different models, a cascade model and a thermal model [21]. Both descriptions failed (see the open point in Fig.1b), which seems to indicate that these ratios require a new reaction mechanism. The E896 data will allow to replace the indirect $\overline{\Lambda}/\overline{p}$ measurement of E864 by a statistically significant direct measurement.

3. RESULTS

Both the DDC and SDDA performed well throughout the four week AGS beam time. The SDDA is the first actual tracking detector based on Silicon Drift Detectors. These detectors have been used before in Heavy-Ion experiments as single plane multiplicity counters [22],[23], but with the advent of the SDDA it was proven that Silicon Drift Detectors are a mature technology that can be used to obtain high precision tracking results. The 15 layer detector contained 7,200 channels, less then 1% of these were inactive during the beam time. The hit position resolution measured during the beam time is about 20 μm in x (the anode direction) and 30 μm in y (the drift direction). The resolution might further improve after the calibrations have been completed, as presently

Figure 1.1 a.) Strangeness enhancement factors based on WA97 measurements, b.) Compilation of $\overline{\Lambda}/\overline{p}$ ratios at the SPS and AGS

the resolution is slightly worse than bench test measurements [24]. The main calibrations of the SDDA are the alignment of the detectors and the drift velocity. A multi dimensional alignment code was developed for the STAR-SVT [25] and is presently applied to the SDDA. The drift velocity in a Silicon detector depends mostly on environmental effects, such as the magnetic field, the operating temperature, the operating voltage. There are also bulk defects which lead to drift non-linearities. These were determined before the beam time during bench tests. The dependence on field, temperature and voltage is calibrated by injecting a well defined charge into the detector at well defined time intervals during the run. Each detector contains eight charge injection lines equally spaced across the active area. The presently achievable position resolution leads to an average momentum resolution of about 1.7% and a mass resolution of about 7.3 MeV (= 0.65%) for the Λ reconstruction. This resolution is comparable to the mass resolution in the DDC.

The analysis of data is presently in progress in both detector subsystems. The DDC analysis focuses on the H-Dibaryon reconstruction and uses the Λ reconstruction mostly for calibration purposes. The large amount of unsuppressed data (1.5 TByte = 100 Million Events) was filtered with the condition of a large rigidity proton leaving the chamber. This filter is very efficient for H-candidates and reduced the data volume by an order of magnitude.

The SDDA is a slow detector recording data at a 1 Hz acquisition rate, but it has a large number of pixels (61,400 pixels/detector) and thus the unsuppressed data volume (1.3 TByte = 650,000 events) is comparable to that of the DDC. In the case of the SDDA the focus of the analysis is to reconstruct decay particles of strange baryons, which are present in every event. Therefore each event had to be recorded. The main data reduction mechanism here is the elimination of empty pixels (zero-suppression). In this way, the SDDA data volume was reduced by a factor 14 to 90 GByte.

Table 1 and 2 show the expected number of strange particles in the SDDA and DDC, based on the actual number of recorded central Au-Au events. Realistic reconstruction efficiencies, based on detailed simulations including detector response and noise levels, were taken into account. The initial particle multiplicities are based on RQMD [18] and a simulation by Carl Dover [1] for the strange baryons and the H-Dibaryon, respectively.

Table 1.1 Strange Particle Yields in the SDDA

SDDA yields/event	Λ	$\overline{\Lambda}$	Ξ	$\overline{p}$	H
generated in RQMD	15	0.045	0.4	0.015	0.1
geometrical acceptance	3.5	0.01	0.04	0.011	0.003
reconstructed	0.3	6×10^{-4}	7×10^{-4}	4×10^{-4}	2×10^{-4}
number of particles in SDDA	200,000	400	450	250	100

Table 1.2 Table 2: Strange Particle Yield in the DDC

DDC yields/event	Λ	H
generated in RQMD	15	0.1
geometrical acceptance	0.07	8×10^{-6}
reconstructed	0.0056	2.5×10^{-6}
number of particles in SDDA	450,000	200

3.1 PRELIMINARY DDC RESULTS

Both detector systems developed independent tracking software. Typical online tracking results in the DDC were shown at a previous Nuclear Dynamics conference [26]. Fig.2a shows a preliminary Armenteros plot based on the complete filtered DDC data set. The filter favors the Λ reconstruction over the $\overline{\Lambda}$ reconstruction by requiring a stiff proton rather than a $\overline{p}$. This leads to the asymmetry in the plot. The resulting Λ mass peak is shown in Fig.3

The H-Dibaryon analysis also includes a cut on the Armenteros plot. Fig.2b shows a simulation of the H-Dibaryon Armenteros distribution compared to the Λ distribution. A potential background in the H-Dibaryon sample is the K_s^0, but the stiff positive track requirement cleans up the sample considerably. The present status of the analysis is that we are in the process of eliminating background contributions in a sample of around 200 H-candidates.

Figure 1.2 a.) Armenteros plot based on the complete filtered DDC data set; b.) Simulation of the H-Dibaryon signal in an Armenteros plot

3.2 PRELIMINARY SDDA RESULTS

Fig.4 shows the reconstructed tracks of a typical central Au-Au event in the Silicon Drift Detector Array. The strong magnetic field leads to large deflections of the tracks. The field was mapped very carefully before the beam time, allowing us to use a Runge-Kutta algorithm based on the field map to correct for field asymmetries and to extrapolate the tracks accurately to the primary vertex. The primary vertex resolution is presently about 1 mm, we expect to improve on this number by about a factor three based on better calibrations.

Figure 1.3 Λ mass reconstruction based on the measurements in the DDC

Fig.5 shows the preliminary Λ mass reconstruction result based on a very small event sample of 300 events (0.05% of the complete data set). This plot simply demonstrates that the tracking and v0 finding algorithms work. Any improvements in the calibrations will lead to further improvements in the reconstruction efficiency.

Figure 1.4 Track reconstruction in the SDDA for a typical central Au-Au event

Figure 1.5 Preliminary Λ mass reconstruction based on 0.05% of the SDDA data set

4. SUMMARY

E896 has recorded a large number of strange baryon and possible H-Dibaryon candidates during its four week beam time in 1998. The present level of the analysis shows that these measurements will lead to conclusive results on strangeness production and strangeness enhancement at mid rapidity in the heaviest system at the AGS. These data will have to be compared to measurements from CERN which hint at an onset of new phenomena at higher energies.

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